Efficiency in Water and Sanitation Sector. A Survey on Empirical Literature

Carlos Romero[1] y Gustavo Ferro[2]

Working Paper Nº 22

ISBN: 978-987-519-133-4

(May 2007)

CEER
Centro de Estudios Económicos de la Regulación
Universidad Argentina de la Empresa
Lima 717
C1053AAO Buenos Aires, Argentina
Telephone / Fax: 54-11-43797693
E-mail: ceer@uade.edu.ar
http://www.uade.edu.ar

[1] E-mail: cromero@uade.edu.ar
[2] E-mail: gferro@uade.edu.ar

Efficiency in Water and Sanitation Sector. A Survey on Empirical Literature

Carlos Romero[3] y Gustavo Ferro[4]

Gustavo Ferro

Carlos Romero

ISBN: 978-987-519-133-4

Queda hecho el depósito legal que marca la ley 11.723

Catalogación en fuente:

Ferro, Gustavo
Efficiency in water and sanitation sector : a survey on empirical literature / Gustavo Ferro y Carlos Romero. - 1a ed. - Buenos Aires : Universidad Argentina de la Empresa - UADE, 2007.
25 p. ; 29x21 cm. - (Working paper; 22)

ISBN 978-987-519-133-4

1. Economía. 2. Servicios Públicos. I. Romero, Carlos II. Título
CDD 354

Fecha de catalogación: 27/06/2007

[3] E-mail: cromero@uade.edu.ar
[4] E-mail: gferro@uade.edu.ar

Efficiency in Water and Sanitation Sector. A Survey on Empirical Literature

Carlos Romero[5] y Gustavo Ferro[6]

Abstract

In this paper, it was made an exhaustive survey of the literature related with cost and production frontiers in the water and sanitation sector. The survey shed light in order to determine the variables to choose in the model to be estimated in a further empirical estimation developed for the Latin American Region by the authors.

[5] E-mail: cromero@uade.edu.ar
[6] E-mail: gferro@uade.edu.ar

I-Introduction

A detailed overview of the literature was done, to recognize the set of variables that have been included en previous studies. The survey also was useful to think other variables not previously studied and to apply them to the estimates. In the survey it was applied a double criteria: studies was grouped by countries or regions, and in a chronological order.

II-England and Wales[7]

[7] After its privatization in 1989, the water and sewerage industry of England and Wales faced a new RPI+K regulatory price cap, a system that is a variant of the typical RPI-X regulation regime in the UK. The regulation was designed both to encourage increased efficiency and also provide funding for the substantial capital investments, which were necessitated by the tightening of environmental and drinking water standards after privatization. In RPI+K formula, K is –X+Q. X represents the amount by which each company has to reduce costs in real terms, and Q reflects the expenditure necessary to meet the higher quality levels set by the European Community directive on water quality. The efficiency factor, X, reflects OFWAT's assessment of each company's scope to reduce its unit costs over a five year period, and a Q factor to reflect higher costs resulting from meeting stricter water quality standards. Water quality is policed by the Drinking Water Inspectorate (DWI) and the Environmental Agency (EA).

The industry has had to undertake much capital expenditure to meet the new water quality requirements and to make up for a large backlog of investment needs while under state ownership. Therefore, in the ten years following privatization, the K factor in the price cap was positive, leading to sharply higher water and sewerage service prices for consumers. However, in the price determinations for the 2000-2005 periods, the companies were required to reduce their prices by an average of 2.1 percent per annum over the quinquennium. The WaSCs and the WoCs have combined annual revenue of almost 7 billion pounds a year, of which between 40 percent and 50 percent is to meet environmental requirements set by either national government or the EU. By contrast, the volume of water and sewerage output supplied has been fairly static with an average annual growth rate of only 0.7 percent since 1990. The WaSCs provide water supply, water treatment and water distribution for near 80% of all connected properties in England and Wales, alongside all sewerage treatment, collection and disposal. They also account for 60% of the industry's investment. WoCs declined from the original 29 to 20 in 1993, and to 12 currently, through a combination of takeovers by WaSCs or mergers with other WoCs. By 2003, the WaSCs accounted for about 81% of connected customers, 82% of water volumes delivered as well as 100% of sewerage properties served.

While average annual OPEX productivity growth has declined moderately from 2.92 to 1.76 percent over 1993-2003, regulatory tightening appears to have had a small statistically significant positive impact on OPEX productivity growth. Saal and Reid (2004) results suggest that overall WaSC OPEX productivity growth rates have not been detrimentally influenced by improved drinking water and environmental quality standards.

The rationale for the structure of regulation for the industry can be explained in terms of the three sources of market failure commonly observed in water and sewerage sectors: monopoly power, asymmetric information about product quality and environmental externalities. Since its first review in 1994, OFWAT has developed a comparative competition approach based on econometric modelling of unit costs to inform the setting of its X factors. These are based on a proportion of the company-specific scope for efficiency improvement identified through the comparative assessments, although the detail of OFWAT's methodology has changed at successive price reviews in 1994, 1999 and 2004 in line with its judgement about the incentives to improve efficiency.

The economic regulation of the privatised water industry can be divided into distinct regulatory periods represented by the term of the successive price controls. In the first regulatory period from privatisation to 1995, price caps were set by Government and not OFWAT. The average annual WaSC K factor for +5% per annum during this period was relatively lax, and was designed to ensure the success of the privatisation

In Price (1993), on the English and Wales industry, the relevant output indicator is WATER DELIVERD TO CLIENTS. DENSITY, measured as CONNECTIONS BY MAIN LENGTH, was not found significant as an explanatory variable. PUMPING was found positive associated with OPEX. For big consumptions two proxies were used: AVERAGE DISTRIBUTED VOLUME TO MEASURED NON-RESIDENTIAL PROPERTIES, and the WATER TO RESIDENTIAL CLIENTS/WATER TO ALL CLIENTS. Both variables were strongly correlated. For CAPITAL INPUT, there were used GROSS AND NET ASSET VALUES BY MAIN LENGTH and the ratio GROSS/NET ASSETS. There were not found significant relationship. To control by regional effects, there were used four REGIONAL DUMMIES. No one was significant. Peak demand was not considered. There was included one SEWERAGE DUMMY between WaSCs and WoCs. It was not significant. Quality of service and product were not included because of its multidimensionality and the lack of a satisfactory synthetic measure.

The more satisfactory model relates OPEX BY UNIT OF WATER DELIVERED, with PROPORTION OF WATER WITH MORE TREATMENT THAN A SIMPLE DISINFECTION, PROPORTION OF WASTE WATER WITH PRIMARY TREATMENT, AVERAGE PUMPING AS A PROPORTION OF WATER DELIVERED, the AVERAGE SIZE OF UNDERGROUND SOURCES weighted by the PROPORTION THAT UNDERGROUND WATER REPRESENTS ON THE TOTAL, PROPORTION OF MEASURED WATER DELIVERED TO NON RESIDENTIAL CLIENTS, and THE PROPORTION OF UNDERGROUND WATER WITH A SIMPLE DISINFECTION.

Stewart (1993) developed estimations of cost functions for the OFWAT system. As the principal explanatory variables they are advanced the LENGTH OF THE NETWORK and the VOLUME OF WATER DELIVERED, from standardised OFWAT measurements of distributed water. The proposed model explains OPEX as a function of LENGTH OF MAINS, VOLUME OF WATER DELIVERED, the AMOUNT OF BILLED PROPERTIES, WATER PUT IN THE DISTRIBUTION SYSTEM and the MEASURED VOLUME OF WATER DISTRIBUTED TO NON RESIDENTIAL CLIENTS.

Stewart (1994), studied sewerage costs in the OFWAT system in the period 1992-93. The DIRECT COSTS OF SEWERAGE plus IMPUTED GENERAL AND MAINTENANCE EXPENSES are explained as a function of the VOLUME OF WASTE WATER and the LENGTH OF MAINS, the VOLUME OF DOMESTIC SEWERAGE

---

flotation. The 1994 price review set significantly tighter price caps with an average WaSC K factor of +1.4% for the period from 1996 to 2000. In the 1999 price review, price caps were further tightening and, for the first time, prices fell in real terms over the period 2001-2005 with average K factor of –1.5% per annum. The effective X factor for total opex expenditures for an average WaSC in the 1994, 1999, and 2004 reviews respectively averaged 2, 2.83 and 1.41%.

The quality regulators play a pivotal role in OFWAT's price setting process through its recommendation to Government on the scale of the required improvements. In practice, OFWAT's policy has been to only make allowance in price limits for expenditure required to meet new standards where this is required by Ministerial guidance and the quality regulator has approved the investment projects or operational solutions proposed by the water companies. During the 1993 to 2003 period, WaSC investment relating to new drinking water quality standards has been of the order of 5.8 billion Pounds in 2003 prices or 31% of total capital investment in water supply for the same period. Investment to improve environmental quality has been overwhelmingly concentrated in the sewerage service to meet the requirements of EU water quality directives. In the period 1993-2003 investment expenditure was around 9.4 billion Pounds in 2003 prices, or 48.2% of total sewerage capital investment over the same period.

OUTPUT is proxied by the RATIO BETWEEN THE RESIDENTIAL CONNECTED POPULATION TO SEWERAGE SYSTEM, the AMOUNT OF POPULATION IN HOLIDAYS –important in some locations-, the ESTIMATED VOLUME OF COMMERCIAL WASTE WATER, also is considered the AVERAGE RAIN IN EACH AREA and the AREA itself.

Bosworth, Stoneman and Thanassoulis (1996) extended Steward (1993 and 1994) in a number of directions. They examined the use of production and cost functions, discussed conceptual issues concerning the functional form to be chosen, measurement problems and the ideal type of data. The translog specification is selected, because of its properties: the scale elasticity varies with output level and the factor proportion, the elasticity of substitution also varies with the output level and the factor proportions, with some caveats it nests other more restrictive functional forms.

Botasso and Conti (2003) analyzed the evolution of operating costs efficiency for the English and Welsh sanitation sector over the period 1995-2001, by estimating a stochastic cost frontier. The stochastic cost frontier approach modified in order to account for possible heteroskedasticity problems arising from large size differential in utilities. The main aim of the paper is to provide an overall picture of the industry cost inefficiency. This has been reduced in the time being, and differences between providers have narrowed. Privatisation took place in 1989. In 1995 the price cap formula was modified to introduce yardstick competition in the industry.

The study used an unbalanced panel of 177 firm observations on WaSCs and WoCs over 1995-2001. They focused only on the water service. OPEX were estimated as a function of UNIT LABOUR COSTS, OUTPUT (proxied by the AMOUNT OF WATER DELIVERED), LENGTH OF MAINS, AVERAGE PUMPING HEADS, PROPORTION OF RIVER SOURCES ON TOTAL WATER DELIVERED, SHARE OF WATER DELIVERED TO NON-HOUSEHOLDS CUSTOMERS ON TOTAL WATER DELIVERED, POPULATION DENSITY, a proxy for FIRM's SIZE: AMOUNT OF WATER INTRODUCED INTO THE DISTRIBUTION MAINS and the STOCK OF CAPITAL proxied by the MODERN EQUIVALENT ASSET ESTIMATION OF THE REPLACEMENT COSTS OF NET TANGIBLE ASSETS.

They adopt a cost function approach since they assume that firms were price takers on inputs markets and that output is exogenously determined. In particular, they considered a variable cost function as they assume capital stock as a quasi-fixed input. The technology is modelled as a Tran logarithmic variable cost function. Some variables, which influence the technology, were included to account for exogenous differences in the environment: a SEWERAGE DUMMY and TIME DUMMIES were included.

The sample has large firms' size variations, which is likely to generate heteroskedasticity problems. In the three models estimated by ML, the coefficients of OUTPUT and WAGE elasticity are positive, as expected. Estimates of the cost elasticity with respect to CAPITAL were positive, but not significant. Positive cost elasticity with respect to AVERAGE PUMPING HEAD and RIVER SOURCES, show that those variables significantly raise variable costs. TIME varying intercepts are only significant and negative for 2000 and 2001, showing a downward shift of the cost frontier. The inclusion of the SEWERAGE DUMMY reflects cost advantages for the joint production of water and sewerage products.

Saal et al (2004) estimated a quality-adjusted input distance function, with stochastic frontier techniques, in order to estimate productivity growth rates for the period 1985-2000. Productivity is decomposed so as to account for the impact of technical change, efficiency change, and scale change. These estimates allow a more careful consideration of how and whether privatization and the RPI+K system price cap regime affected productivity growth in the industry. They suggest that while technical change improved after privatization, productivity growth did not, thereby suggesting that firms struggled to keep up with technical advances in water services after privatization. Moreover, they also suggest that diseconomies of scale contributed negatively to productivity growth.

Failure to incorporate improvements in water quality into the output measure will seriously depress the resulting productivity growth in the industry. The research reported in this paper is directly concerned with the impact of privatization and regulation on productivity growth during the period 1985 to 2000 and builds on earlier work. The research covers periods both before and after 1989 and does take account of water quality improvements. The study is concerned only with the performance of the WaSCs, which dominate the industry.

An input distance function provides an input oriented measure of technical efficiency by finding the maximum possible radial contraction of an input vector that can occur while still producing output vector.

The privatized water and sewerage companies are multi-output producers. Recent work have emphasized that significant modelling improvements result in both the physical volume of water and sewerage output, as well as data on the number of water and sewerage customers, are modelled as outputs. Such specification is appropriate if we consider that there are distinct output characteristics associated with the physical volume of water supply and sewerage treatment, as opposed simply to the provision of connections to water and sewerage network customers. Moreover, the input requirements of providing network access to an additional water or sewerage customer are substantially different from the input requirements of delivering additional water or sewerage treatment services to an existing customer. It is similarly appropriate to model an integrated water and sewerage utility as a multiple output producer of connections with water customers, connections with sewerage customers, physical water supply, and physical sewerage treatment load, and this approach is followed in this paper.

Each WASC's WATER QUALITY INDEX, is defined as the ratio of the average percentage of each WASC's water supply zones that are compliant with key water quality parameters, relative to the average compliance percentage for England and Wales in 1990. Turning to SEWERAGE QUALITY, a weighted average of river quality and bathing quality relative to the quality level for all England and Wales in 1990 was chosen as the best available proxy. In principle, these indices or transformations of them could be included as exogenous factors influencing input requirements and/or relative efficiency. Their CAPITAL STOCK variable is based on the modern equivalent asset estimation of the replacement cost of net tangible fixed assets, as provided in each WASC's regulatory accounts for the years 1990 to 2000.

As with all variables employed in this paper, the need to employ consistent data for both the pre and post privatization period limited the choice of potential exogenous factors. Nevertheless, it was possible to identify several potential z-factors with consistent data for the entire 1985-2000 periods. The final model specification included four of these. These are the PROPORTION OF WATER ABSTRACTIONS FROM UNDERGROUND SOURCES, the RATIO OF TRADE EFFLUENT LOADS TO RESIDENT POPULATION, BATHING WATER INTENSITY, and the PROPORTION OF METERED CONNECTED WATER PROPERTIES.

The PROPORTION OF WATER ABSTRACTIONS FROM UNDERGROUND SOURCES allows controlling for substantial differences in water supply and the resulting impact on input requirements. Underground water sources will require greater treatment costs. Similarly, data on TRADE EFFLUENT intensity should capture differences in the relative intensity of industrial effluent treatment, which might have a significant influence on sewerage treatment input requirements. Greater industrial effluent treatment can be expected to result in higher input requirements.

The results suggest that while privatization and the imposition of RPI+K regulation was meant to stimulate efficiency improvements, the combination of transitional efficiency declines probably attributable to reorganization at privatization, as well as initially lax price controls imposed at privatization to assist a successful sale, meant that by the year 2000 efficiency levels in the water and sewerage industry had not recovered to their level at privatization.

Saal and Reid (2004) examined how both economic and environmental regulation in the English and Welsh water and sanitation sector has influenced productivity growth in the industry. Saal and Reid (2004), employed a quality adjusted quasi-fixed capital trans-logarithmic variable cost function to provide estimates of average annual operating cost (OPEX) productivity growth for English and Welsh water and sewerage companies (WaSCs). In order to analyse quality, as well as the significant tightening of price cap regulation after 1995, they also developed a framework within which standard productivity measures can be employed to analyse these issues.

In order to estimate WaSC OPEX productivity growth rates it is employed a quasi-fixed capital translog model of operating costs (OPEX). The quasi-fixed nature of water industry assets makes quasi-fixed variable cost models more appropriate, but such models are less frequent in the literature.

The generic model includes the standard input price (W), output (Y) capital (K) and time (t) variables and interactions between these variables. However, it also includes the less standard hedonic (H) variables, which are assumed to be exogenous conditioning factors such as network characteristics, environmental, and/or hedonic characteristics, measured in levels. These variables are included to take into account characteristics other than outputs, prices, and capital stocks, which may have a significant influence on OPEX costs, but can also be assumed to be outside of full WaSC managerial control.

As economic theory suggests that cost functions should be homogenous of degree one in input prices, it is necessary to impose this homogeneity onto the system of equations. This is accomplished by estimating the above system after dropping one cost share equation, and one set of input price interaction terms. This imposition of homogeneity requires that the input prices and variable cost variables must be divided by the dropped input price before taking logarithms. Secondly, they employ another standard technique of trans-logarithmic modelling, which is to normalize the data about its full sample mean before estimating the model.

Data for LABOUR PRICES (W1) was sourced directly from the statutory accounts of the appointed water companies, with the average nominal price for labour inputs computed as total salaries and remunerations divided by full time equivalent employees. Given its definition as total OPEX costs less labour costs, OTHER INPUT COSTS reflects a composite set of heterogeneous inputs. Given its heterogeneous nature, imputing a price for this category of input is difficult. A PRICE INDEX FOR OTHER INPUTS (W2) is constructed as a unit cost of other inputs relative to an aggregate output index, which captures the relative quantity of both water service and sewerage service outputs.

Regarding hedonic variables, the purpose of their inclusion is to control for exogenous influences on OPEX during the sample period. Several alternative hedonic variables were rejected from the specification due to statistical insignificance and are therefore not further discussed in the main text. These included DISTRIBUTION LOSSES (leakage), the NUMBER OF METERED PROPERTIES, the NUMBER OF PROPERTIES AT RISK OF SEWERAGE FLOODING, TRADE EFFLUENT VOLUMES, and the VOLUMES OF WATER FROM UNDERGROUND SOURCES. The first two hedonic measures were adopted to measure the substantial increase in drinking water environmental quality over the 1993-2003 period. A relative measure of DRINKING WATER QUALITY Q1 was first calculated by employing data to determine the percentage of a WaSC's drinking water supply zones that were fully compliant with 16 different drinking water standards[8]. Q1 times the water supply population is the defined qualitative variable H1.

The substantial program of capital investment since WaSC privatization has in large part been concentrated on the extension of secondary level sewage treatment to meet EU environmental standards. Therefore, trends in secondary treatment should provide a measure of the improvement in environmental quality as WaSCs have invested to meet rising standards. The ESTIMATED POPULATION RECEIVING AT LEAST SECONDARY TREATMENT OF SEWERAGE is H2.

A similar quality related hedonic variable is the NUMBER OF CONNECTED WATER SERVICE PROPERTIES WITH WATER PRESSURE BELOW THE REFERENCE LEVEL set by OFWAT (H3). Improvements in water pressure require substantial expenditure on leakage control and improved system design and management. Moreover, improved pressure was an important quality parameter pursued by OFWAT in the years following privatisation.

As the previous literature was suggested that controlling for connections is important when estimating water industry cost functions, they have therefore included both the NUMBER OF CONNECTED SEWERAGE PROPERTIES (H4) and NUMBER OF CONNECTED WATER SERVICE PROPERTIES (H5) as hedonic variables.

---

[8] Coliforms, faecal coliforms, colour, turbidity, odor, taste, hydrogen ion, nitrate, nitrite, aluminum, iron, manganese, lead, PAH, Trihalomethanes, and total pesticides.

The final hedonic variables to be included in the specification are SEWERAGE SERVICE DENSITY (H6) defined as population per kilometre of sewer, and WATER SERVICE DENSITY (H7) defined as population per kilometre of water main. Alternative density variables defined as POPULATION PER SERVICE AREA were found to be statistically insignificant, thereby indicating that the distribution of population along service mains is a more appropriate density measure.

Saal and Parker (2005) pointed out that in its 1994, 1999 and 2004 price reviews, OFWAT has assessed the performance of companies by employing a set of cross sectional models at the function level (water distribution, water treatment, etcetera) and then aggregating these functional models in order to generate separate assessments of a company's performance in water operations and sewerage operations. Moreover, in assessing the performance of water operations, OFWAT has implicitly assumed that the water and sewerage operations of a WASC are fully separable. This is because it has assessed the water operations of both WaSCs and WoCs against jointly estimated common frontiers.

Saal and Parker (2005) employed a quality-adjusted input distance function and stochastic frontier techniques to estimate productivity growth rates for the water operations of England and Wales' water and sewerage industry. While an output distance function is built on the assumption that managers wish to maximize output usage for given inputs, an input distance function assumes that managers wish to minimize input usage given current output levels. The results suggest that there is substantial scope for employing these techniques in assessing water operations efficiency. These methods also allow productivity growth to be decomposed so as to account for the impact of technical change, efficiency change, and scale change on performance. The results also indicate that within the context of a panel stochastic frontier model, it is statistically inappropriate to assume that WaSCs and WoCs share a common frontier. Such an assumption would result in biased estimates of productivity growth and efficiency. The study is motivated by the desire to determine if OFWAT's current approach (of assessing the water operations of both WaSCs and WoCs against jointly estimated common cross sectional frontiers), can be extended to the panel assessment of overall water operations performance.

III-Italy

Fraquelli and Moiso (2005), analysed the ongoing reform of the Italian water sector, with particular attention to the industry cost efficiency and to the assessment of scale economies at ATO level, by estimating a stochastic cost frontier. The ATOs (Ambiti Territoriali Ottimali) should be local optimum size areas defined by regional bodies, where the management of water and sewerage services is unified. They analysed 18 ATOs through their operational and strategic planning which provides the management guidelines for the next 20 years. In particular, Fraquelli and Moiso (2005) estimated a trans-logarithmic cost frontier to assess the behaviour of returns to scale, the inefficiency score and the impact of network characteristics. Galli law mandated the creation of 91 ATOs, where the management of water service must be unified. A vertical integrated structure is supposed to minimize the sum of production and transaction costs: in each territorial area the same firm will manage the water and sewerage service and wastewater treatment. The main problems in the Italian water system were: service fragmentation, low efficiency and low size, insufficient water supply (occurring during summertime); low quality of water and services and, consequently, level of customer satisfaction; tariffs (in many cases not even covering costs and among the lowest in Europe. The union and the strong reduction of some 13,000 firms should guarantee the minimum efficient size, a rationalization of investments and a better coordination of joint costs of water service.

The ATO management has to be assigned, through a competitive bidding, to one private or mixed private-public firm. Public firms can maintain their concession without a competitive bidding, but cannot compete for other ATOs; the private company continues to operate up to the expiry of its own concession. The major problem still remains the size of the ATOs and the size of the firms inside them. In every single ATO the service is managed by a large number of units. The goals are based on the so-called Piano d'Ambito, a plan implemented by single utility firms under the control of the Water Authorities. The Piano finds and faces the peculiar problems of each ATO. It also includes the financial plan and the tariff systems. Tariffs must cover operational and financial costs and, through a price cap mechanism, stimulate the efficiency of utility companies.

The empirical research is based on a thirty-year unbalanced panel data of business plans of 18 ATOs at national level (out of 62 available), over a period of 20-30 years, for a total of 407 observations. In order to verify both scale economies and inefficiency, was estimated a stochastic cost frontier. The presence of scale economies gives a measure of the potential cost reduction related to the increase of the size. On the other hand, the measure of the inefficiency is a quality index of the resources allocation provided by each ATO. The results show that –on average- inefficiency score is about 21%, partially explained by network characteristics. On the other hand, the presence of relevant scale economies suggests that a reduction in local fragmentation could improve the supply structure of water service in Italy.

The trans-logarithmic specification is a flexible function form, imposing no a priori restriction on production technology. In particular, a stochastic cost frontier approach was adopted, enabling to analyse the evolution of inefficiency over time and between firms, distinguishing cost reductions induced by technical change from those deriving from efficiency improvements. This methodology computes the cost deviation from the best practice frontier per year and per firm, and this deviation is attributed to both inefficiency and other random effects.

In the study, the attention is focused on the Italian tariff computation model. This is based on the operational costs added to the financial cost of the capital (equity and debts) with the deduction of a price cap improvement of efficiency term. The output is measured by the TOTAL VOLUME OF WATER DELIVERED. Input factors mainly consist in LABOUR, ENERGY, MATERIALS, SERVICES and CAPITAL. The TOTAL COST depends on the AMOUNT OF WATER DELIVERED, the PRICE OF LABOUR, ENERGY PRICE and MATERIALS, SERVICES and CAPITAL. In addition to those variables, were included NETWORK LENGTH and an indicator of LEVEL OF LOSSES as output characteristics. A TIME TREND variable accounts for technological progress.

The LABOUR PRICE was obtained by dividing the TOTAL LABOUR COST by the NUMBER OF EMPLOYEES, the ENERGY PRICE by dividing the TOTAL

EXPENSES IN ELECTRICITY by the WATER INTRODUCED IN THE NETWORK, the PRICE OF MATERIAL, SERVICES AND CAPITAL by dividing its cost by the network length. The DUMMY FOR LOSSES takes value one when in the ATO the volume of losses (introduced water minus distributed water) is greater than the average of the whole sample. The average value was considered as reference given that the losses are a structural phenomenon in the water industry. The model was estimated by ML method in order to simultaneously estimate the parameters of the stochastic cost frontier and the variables of the inefficiency model.

The model that better explains the relative efficiency of firms is linear between the u term and the POPULATION DENSITY, obtained by dividing the NUMBER OF RESIDENTS by the NETWORK LENGTH. DENSITY may have ambiguous effects on costs inefficiency. A higher value of this variable is expected to reduce cost inefficiency because it is cheaper to distribute water of not extensively scattered customers. On the other hand, a higher density may create congestion problems. All variables were normalized to their sample mean and are in natural logarithm. All signs of the first order parameters are as expected. Variable costs are in a very weak relation with the time variable: there is not an annual cost reduction due to technical progress. As expected, for smaller firms the economies of output density are very high. As the delivered water increases, the value decreases but remains always up to 1. The results show the presence of strong economies of scale, that fall up to about 1 million inhabitants. In the Italian water sector the average size of the ATOs is two thirds of the former. The results suggest that existing ATOs can obtain cost reduction through further mergers, approaching the optimum size. The efficiency evolution over time was investigated and it was found evidence of increasing inefficiency rates followed by decreasing rates over time. The results show a positive relationship between inefficiency and population density, evidence of possible congestion problems in the ATOs with a higher density.

IV-Asia

The cost frontier for Asia estimated by Estache and Rossi (1999) comprises 50 firms from a database provided by the Asian Development Bank for 1995. The final model used to calculate the efficiency measures related COSTS against SALARIES, CLIENTS, DENSITY OF POPULATION, CONNEXIONS, STRUCTURE –RESIDENTIAL SALES ON TOTAL SALES-, quality measured as NUMBER OF HOURS OF WATER AVAILABILITY AND A DUMMY FOR CONVENTIONAL TREATMENT OF THE RAW WATER. The methodology used was COLS. It was also calculated a regression by ML, with similar results. The consistency of the measures was evaluated.

In order to assess consistency, they used Bauer (1998) criteria:

1) The efficiency measures generated by the various frontiers methods must yield similar averages and standard deviations.

2) They must rank firms in a similar way.

3) They must identify the same best and worse firms.

4) They must be reasonably consistent over time and should not vary significantly from year to year.

5) They must be reasonable consistent with the results expected from the developments in the industry.

6) They must be reasonably consistent with other performance measures used by the regulators (like partial productivity measures).

Estache and Rossi (2002), advanced over they previous work. The data provides comparable information for all the companies, but just for one year. They do not contain information of the asset base. The estimated function is in line with practice in previous studies. Since the only input price available is for labour, an ad hoc cost function was estimated. The dependent variable is OPEX. Some environmental variables were included, POPULATION DENSITY, the PERCENTAGE OF WATER FROM SURFACE SOURCES, the PERCENTAGE OF METERED CONNEXIONS (higher administrative costs), and HOURS PER DAY OF WATER AVAILABILITY. Three dummies were included: CONCESSION, PRIVATE ADMINISTRATION, and OTHER PRIVATE SECTOR PARTICIPATION. The initial model calculated COSTS as a function of SALARIES, CLIENTS, CONNEXIONS, PRODUCTION, DENSITY, WATER FROM SURFACE SOURCES, QUALITY, METERS, and 5 DUMMIES. For OLS, COLS and ML estimates, the signs of the coefficients are as expected.

V-Latin America

Mobbs and Glennie (2005) developed DEA calculations with ADERASA database for 2003, relating the ratio of a weighted sum of outputs to a weighted sum of inputs. The weights have been calculated to maximize each organisation's efficiency score. An efficiency frontier is derived from the most efficient organizations, and less efficient organizations are compared with the frontier. Peer organisations' are identified for each organization not on the frontier.

A number of models were run. As inputs there were chosen TOTAL AMOUNT BILLED and STAFF. As outputs were considered POPULATION SERVED, CLIENTS, CONNECTIONS, LENGTH OF MAINS and WATER SOLD. No relationship between climate and topography, on one hand, and efficiency, on the other hand, could be found from the data. Several of the "least efficient" utilities are in small countries, serving a large area. Private utilities tend to have fewer staff than similar public utilities. There does not appear to be a strong relationship between the number of people served by a utility and its efficiency. Utilities where the sewer network is nearly as big as the water supply network tend to be more efficient, perhaps indicating the economies made possible by shared functions such as billing. Regression analysis was tried as an alternative, but did not add any useful information to that obtained from DEA. Monetary measures have been converted to PPP, which bases exchange rates on the local costs of buying a basket of goods.

V-1 Brazil[9]

Crampes et al (1997) estimated a cost function for Brazilian water sector. They applied the same variables of the Stewart (1993) study and also include the VOLUME OF WATER PRODUCED, the RATIO BETWEEN THE VOLUME OF BILLED WATER AND PRODUCED WATER, and the RATIO BETWEEN CONNEXIONS AND STAFF. They used weighted least squares.

Moreira and Fonseca (2005), suggest evaluation criteria for productivity estimation arising from DEA and SFA. They named their criteria "Classification Error Index" (CEI). They made an empirical investigation to compare those models and a Bayesian approach to the SFA model in order to derive the expected value of productivity. Their results show that the greater CEIs (worst results) are related with variable returns to scale when DEA is used, with small samples when SFA is used, and with lower ratio between productivity and error variance for both models.

Tupper and Resende (2003) quantified the relative efficiencies of state-level water and sewage companies in Brazil during 1996-2000. Relative efficiency scores obtained by DEA indicate that sub-optimal performance is salient for some utilities. The complementary between DEA and econometric procedures is explored. The comparison of actual costs and reimbursed values defined by the comparative efficiency analysis makes salient different patterns across the different utilities and the possibility of important cost savings. In contrast with the majority of utilities in Brazil, the water and sewage sector has not been privatised and remains structured around a set of state and municipal firms. The paper also discuss the feasibility of implementing yardstick schemes. In order to reach those goals, they were combined the flexible relative efficiency measurement approach of DEA with econometric estimation.

In Brazil there are 27 state companies. Among these, there are 25 companies with mixed ownership (but public management). In 2000, together these 27 companies supplied around 3823 municipalities (69% of the total of Brazil). The main data source was provided by the annual diagnoses generated by the SNIS. The referred report on state services has been continuously published since 1995. The authors had to confine our sample period to 1996-2000. The present study needed to focus on 20 of the 27 existing companies given incomplete or non-existent data. The inputs and outputs selected for the analysis are as

[9] In the Brazilian case there is a substantial deficit in water and sewage provision that had reached 9% and 51% of the population respectively in 1996. In 1971, a national plan for water and sewage provision in urban areas was created. Among the targets established by the plan there was a well-defined intention of stimulating state companies instead of municipal companies. The regulatory framework involved traditional ROR and aimed mostly at the financial sustainability of the sector. Tariffs charged by the state companies during the plan involved a system of cross-subsidies between different classes of consumers so as to make the coverage of low-income population tenable. By the same logic, the cross subsidies scheme was extended to municipalities with lower revenue potential. In that case, the adoption of a single state-level tariff (based on global costs) established a cross-subsidy mechanism form municipalities of higher revenue to those of smaller revenues or higher costs. The tariff model based on cross-subsidies had important role on accelerating infrastructure investment for low-income localities, even though the deficit remains high. The conflict of jurisdiction between state and municipalities remain until the present. The problem arises when the state companies operate in an area beyond the territorial limits of a particular municipality. It is possible, that part of the inefficiency sources might be corrected in the future. The co-existence of several regulatory institutions at a more local level, however, is an obstacle for the establishment of a proper regulatory framework.

follows: for inputs were selected LABOUR EXPENSES, OPERATIONAL COSTS AND OTHER COSTS, and for outputs, WATER PRODUCED, TREATED SEWAGE, POPULATION SERVED-WATER and POPULATION SERVED-TREATED SEWAGE. Additional control variables are later introduced in the econometric analysis of the determinants of efficiency. Even though the discrimination among the relative efficiency scores is not overwhelming, one can detect companies with salient sub-optimal performance that may motivate the introduction of efficiency-inducing regulatory mechanisms. Attending heterogeneity of the regions of the country, there were explored some regional factors that are likely to interfere on the determination of productive efficiency. Econometric analysis can provide a useful complement to the efficiency measurement approach of DEA as joint instrument towards the implementation of yardstick schemes. Specifically, were considered as explanatory factors: DENSITY OF WATER NETWORK (POPULATION SERVED-WATER DIVIDED BY THE NETWORK EXTENSION IN KILOMETERS. Utilities that operate in low density areas are likely to be relatively burdened in comparison with utilities that operate in high density areas), DENSITY OF THE SEWAGE NETWORK (POPULATION SERVED IN TERMS OF SEWAGE CAPTURED DIVIDED BY THE NETWORK EXTENSION), INDEX OF WATER LOSSES (VOLUME OF WATER PRODUCED PLUS GROSS IMPORTED PLUS TREATED IMPORTED MINUS VOLUME OF CONSUMED WATER, all divided by VOLUME OF WATER PRODUCED PLUS GROSS IMPORTED PLUS TREATED IMPORTED). The coefficients for density of water and index of losses display the expected sign whereas density of sewerage has a counterintuitive sign but the coefficient is not statistically significant.

Sabbioni (2005) used econometric techniques to measure the relative performance of water and sewerage utilities in Brazil. Three alternative specifications of a stochastic cost frontier were utilized to rank Brazilian firms. The study focuses on parametric approaches to estimate key parameters and test the relative importance of variables.

Sabbioni (2005) utilized the cost function approach as more appropriate, based upon the characteristics of the operating environment of water and sewerage utilities, the ability to deal with multiple outputs, the lack of endogeneity problems, data availability, and technology specification. It was assumed that a water and sewerage utility can maximize its profits (or social surplus) by minimizing the cost of producing some exogenously given output level, subject to the available technology. The focus is on 2002 data, the most recent year with published information, provided 280 observations for the cross-sectional analysis; however missing observations reduce the effective size of the sample, depending on the variables chosen.

Three possible specifications for the cost function were constructed. The first results consist of specifications that deliberately exclude environmental variables. The R-squared for these regressions is higher than 0.90. This set of results consists of three different specifications for the cost function: Volumes Model, Population Model and Connections Model. Each model has one output variable related to water and one output variable related to sewerage (VOLUME OF WATER PRODUCED and VOLUME OF SEWER COLLECTION in the first case, POPULATION SERVED WITH WATER and POPULATION SERVED WITH SEWER in the second case, and, WATER CONNEXIONS and SEWER CONNEXIONS in the third case). Regarding the vector of input prices present in all regressions, the variable WAGES was estimated in the usual way, as the ratio of total salaries paid divided by the number of workers in the firm. The WAGE coefficient is always positive and significant. No matter the choice of outputs, all the coefficients are positive and significant in the three regressions.

Variations of the basic models were evaluated to shed light on the environmental issues that may affect the technology of the firms. Environmental variables were tested one by one to isolate their effect on the operating cost and evaluate them in detail. Finally, there were used: DUMMY FOR PURCHASING OF WATER FROM ANOTHER UTILITY, the AVERAGE LITRES OF WATER THAT A HOUSEHOLD CONSUMES in cubic meters per month, REGIONAL DUMMIES and VOLUME OF WATER METERED in cubic meters.

To estimate the efficiency level of the regional firms, they were run three stochastic cost frontier models. By OLS regressions there were found the significant variables for most of the variation in operating cost, but the construction of an efficiency ranking of the firms needs to account for both inefficiency and randomness in the error term. Hence there were performed three stochastic cost frontier regressions (using ML) with exactly the same variables. The error term from these regressions is asymmetric, since it is composed of an error term (random noise in the data) and a non-negative term (that specifically accounts for the deviation in cost attributable entirely to inefficiency, assumed to follow a half-normal distribution). It is shown a strong stability of the value and sign of the coefficients from the OLS versions and the stochastic cost frontier versions. All the variables remain highly significant, which adds more support for their inclusion in the models. The firms in the better and in the worst places are consistently ranked, regardless of which output variable is chosen.

With respect to exogenous factors, it was evaluated the possibility of regional influences on operating costs. Hence it was checked the significance of four regional dummy variables in the three basic models according to where the firm is located. At first glance, there is no evidence that any region affects operating costs in any particular direction (at least in all the specifications). Each model was put through the process of eliminating the less significant regional variables one by one. Northeast (with negative coefficient) and Southeast (with a positive one) were kept in both the population and the connections models because of significant effects. The second analysis of exogenous factors addresses the constraint that some utilities face when they do not own sufficient water to satisfy their demand, and so must purchase water from other firms. There is some evidence that it increases operating costs, but the significance of this result is verified only for the volumes model. The third set of results concerns the effect of population density on operating cost. Counter to the expected, no negative and significant coefficients were found for the density variables in the three specifications. Density of water connections was significant to the population and connections models and with the expected negative sign. Sewerage density proved to be insignificant in all models. The fourth analysis of environmental factors was the evaluation of whether water metering has a positive impact on operating costs. The results indicate that the volume of water metered has a positive effect on operating costs. The result is maintained across the three specifications. The last set of regressions with environmental variables test the hypothesis that larger customers reduce the operating cost of the firm, addressing issues raised in earlier works regarding residential versus commercial customers even though that distinction is not made in the database. Only the volumes model accepts a significant measure of average water consumption, which means that the greater the volume of water delivered to a customer, the lower the total operating cost for the utility.

Water losses could certainly explain differences in operating cost across utilities, but that is something that should be handled by the management of the company. Mainly caused by the inefficient operation of the utility, water losses cannot be considered exogenous parameters that affect the available technology of the firm. Because network length is considered only partially endogenous, it was not controlled for this variable either.

V-2 Peru

Berg and Lin (2005), evaluated the consistency of water utility performance rankings for Peruvian water utilities. DEA and Stochastic Frontier Analysis (SFA) yield similar rankings in this case. The rankings are not highly correlated with those developed by Peruvian water regulator SUNASS, based on partial productivity indices. SUNASS developed a system of indicators and a benchmarking scheme, composed by nine indicators in four areas of efficiency: quality of service (compliance with the residual chlorine rule, continuity of service and percentage of water receiving chemical treatment), coverage of service attained (water coverage and sewerage coverage), management efficiency (operating efficiency, percentage of connections with meters installed and non-payment), and managerial finance efficiency (direct costs and other expenses/revenues). Each indicator expressed as a percentage is multiplied by its weight (1/9) and added to the percentage total per company.

The Berg and Lin (2005) analysis is for 44 firms from 1996 to 1998. The models used as inputs, OPERATING COSTS, WATER LOSSES and the NUMBER OF WATER CONNECTIONS. The outputs were VOLUME OF WATER BILLED (because of high levels of unaccounted for water), NUMBER OF CUSTOMERS, COVERAGE OF SERVICE and CONTINUITY OF SERVICE as quality indicators.

A disadvantage of the production frontier SFA is that it cannot consider multiple inputs and outputs simultaneously. To solve this problem, an input distance function was used: it could describe the multiple-input and multiple-output production technology and does not require assumptions about the behaviour of the companies.

In order to avoid the loss of degrees of freedom, a log-linear function was estimated. The inputs are NUMBER OF EMPLOYEES, OPERATION COSTS and NUMBER OF WATER CONNECTIONS. The outputs are VOLUME OF WATER BILLED, NUMBER OF CUSTOMERS, COVERAGE RATIO and CONTINUITY OF SERVICE. All the terms have the correct signs: output coefficients are negative and inputs coefficients are positive.

Lin (2005) examined how the introduction of quality variables affects comparisons across utilities. The research presented different specifications of stochastic cost frontiers models to illustrate how quality can be incorporated into benchmarking studies. The paper examined the performance of the publicly owned water utilities regulated by SUNASS in Peru, using data from 1996-2001. This study attempted to determine whether the inclusion of quality indicators into the estimations affects the benchmarking results. TOTAL COSTS are calculated from the SUNASS database. The outputs considered are those used in many water studies: VOLUME OF WATER BILLED and the NUMBER OF CUSTOMERS. Because the former is highly correlated with revenues, it was not included as an output. The two input prices are WAGES and CAPITAL PRICE. The WAGES are calculated by TOTAL OUTLAYS ON LABOUR DIVIDED BY THE NUMBER OF EMPLOYEES. The CAPITAL PRICE can be approximated by ANNUAL CAPITAL OUTLAYS DIVIDED BY THE STOCK OF CAPITAL. In this study, capital outlays are approximated by adding depreciation and financial cost (interest payments). Either the NETWORK LENGHT or the number of WATER CONNEXIONS can be used as the proxy for the stock of capital. Because of the lack of data on fuel, chemicals, and power and material costs, the model does not impose the restriction of homogeneity of degree one in prices for estimation purposes. Four variables are used for quality dimensions: ACCOUNTED FOR WATER RATIO, POSITIVE RATE OF CHLORINE TESTS, SERVICE COVERAGE and SERVICE CONTINUITY. ACCOUNTED FOR WATER is 1 minus UNACCOUNTED FOR WATER RATIO (which includes physical and commercial losses). COVERAGE is used as an indicator of service quality, because is a direct measure of water availability to citizens in a municipality. A POSITIVE RATE OF CHLORINE TESTS (% of samples with satisfactory residual chlorine) and CONTINUITY of service are two of the three indicators used by SUNASS to evaluate service quality. An unbalanced panel data sample with 198 observations is used in the estimation. The monetary unit variables have been deflacted. Different distribution models are tested in the study in order to reduce the impact of choosing a specific distribution function arbitrarily. The environmental and quality variables are consider either as influencing the efficiency of a firm or as additional outputs of the cost function. A TIME TREND was added to capture the technical change.

Firstly, it was estimated the frontier model without quality variables. All models with different error specifications yield similar results. All the coefficient of outputs and input prices are significant and consistent with economic theory. The coefficient of the time trend variable is insignificant, which suggests the absence of technological change over this time period. Next, a panel data conditional mean efficiency model is estimated to check the impact of quality indicators on water utility efficiency. Coefficients of output and inputs prices are significant and consistent with economic theory. None of four coefficients of quality indicators are statistically significant. Therefore, it may not be appropriate to treat the quality variables as environmental variables. When the quality variables were treated as additional outputs and included in the cost function, they were all significant and consistent with economic theory. The results indicate that the quality output variables should be included in cost frontier models.

VI-Africa

Estache and Kouassi (2002) analyzed the determinants of the efficiency levels reached by 21 African water utilities, through the estimation of a production frontier for the sector. For lack of better data, they estimate this production function from an unbalanced panel of data for a sample of 21 African water utilities covering the 1995-1997 periods. To contribute to the design of reforms, the paper also quantifies the joint effect of various institutional sources of inefficiencies, and in particular assesses the costs of the interactions between inefficiency and major institutional problems, in particular governance. The measurement of efficiency in the water sector is complicated by the nature of the production process. The main justification for the selection of the specification chosen of a water production function for Africa is the following. First, in most African countries, the production cost structure is not known because of the degree of uncertainty surrounding cost structures is relatively high; therefore it is better to estimate a production function rather than a cost function. Second, in most classical papers, capital and length of network are two key variables; while in the present case, those two variables are highly correlated (multi-co linearity issue). That means that one of these two variables should be used but not both of them. Third, in the specific context of African countries, the number of connections is a very important variable since the average size family is between 7 and 9 for some African countries and even more for other (free rider issue). Finally, the variable time trend should capture technological impact within the water industry in Africa.

The authors apply a transformation to the original data and re-estimate the model in order to get the GLS estimates. The results are very satisfactory. Out of six explanatory variables, four are significant. Results confirm the non-endogeneity of labour as seen from the Hausman simultaneity test. The estimation with the GMM has given similar results. Note also that the GLS is the favourite due to the absence of correlation between the individual effects and the explanatory variables confirmed by the Hausman test.

For the sample analysed and the period covered, the average performance is only 54%. The top performers score high at 85 and 83%, which is close to three times the score of the bottom performers who score between 30, and 35%. The scale indicator suggests that constant return to scale prevails in the water sector in Africa. The rate of technical progress turns out that the impact of technology is very limited in the context of water service utilities in Africa during the period under analysis.

Recent studies have shown that institutional factors at the discretion of the management as well as environmental factors beyond the control of managers or regulators affect water efficiency. Some of the factors cited in the literature are corruption (various indices), governance (various indices), and etcetera. This can be tested form the results obtained here. The efficiency scores of water utilities are examined using a censored tobit model to identify factors influencing inefficiency. The empirical model runs the regression between the inefficiency values against a constant, a CORRUPTION INDEX, a GOVERNANCE INDEX and a DUMMY FOR PRIVATE OR PUBLIC. An important feature of the results is that institutional variables are statistically significant at the five percent level; their signs are also as expected. An interpretation of these results corroborates the fact that corruption is negatively linked to efficiency while governance is positively linked. As a consequence, water utilities should also focus on institutional variables when trying to improve their efficiency score. The dummy variable, which captures the effect of privatization, is statistically significant at the five percent level.

VII-Australia

Woodbury and Dollery (2003) attempts to augment the literature on performance measurement in Australian local government by using DEA with holistic indices of allocative and technical efficiency in NSW municipal water services. It also seeks to incorporate qualitative indicators into efficiency measures. “Best-practice” councils are identified and the underlying causes of municipal water service efficiency are analysed.

In the area of water services, in common with many other public services, the total value of a service cannot be adequately assessed in terms of quantitative outputs alone. For instance, the physical and chemical quality of the water supplied (water quality) and disruptions to supply (reliability) are important qualitative attributes of the final product.

The age of the infrastructure influences the amount of maintenance required to provide continued supply of the service: the type of infrastructure represents the technology used and thus the production function faced by the council; raw water quality determines how much treatment is required to meet the drinking water guidelines; rainfall affects the raw eater quality and so the amount of treatment required; topography influences pumping costs and ease of construction works; the corrosiveness of the soil affects the life of pipework and thus maintenance to keep the system serviceable; population density determines the average amount of pipe required to service each property; seasonal variations in populations may require larger capacity infrastructure to meet standards all year round; and finally, the industrial activity level can influence the average consumption of water.

Six alternative models were used to compare different ways of incorporating service quality measure into the DEA. The use of indicators for separate DEA outputs was unsatisfactory since their scale neutrality was inconsistent with the other outputs and inputs. The adjustment of quantitative outputs by multiplication with aggregate service quality indices provided a superior methodology. Averaging of service quality indicators when compiling the aggregate indices was found, not surprisingly, to be less punitive than either multiplication of the indices or adopting the minimum index number. However, the differences between the more and less punitive alternative models were less than expected.

VIII-Other

Bhattacharyya et al (1995) studied technical efficiency of rural water utilities, using frontier production functions. An indirect production function is developed to model the two-step production process of a local government-controlled firm. Data from 26 rural Nevada water utilities are used to estimate inefficiency in terms of firm-specific variables. A multistep estimation procedure is used instead of single-step maximum likelihood estimation. Model selection tests are used to choose the best model. Privately owned utilities are most efficient; self-governing water districts are the least efficient. Municipal governments operate the most and least efficient utilities.

Renzetti and Dupont (2003) pursued to critically assess what is known regarding the relationship between the ownership and performance of municipal water utilities. Renzetti and Dupont (2003) turn to the empirical evidence from the United States, the United Kingdom and France. These studies reveal that there is no compelling evidence to date of private utilities outperforming public utilities or that privatising water utilities leads to unambiguous improvements in performance. However, there is some evidence that public-private partnerships in these countries may facilitate efficient and sustainable operations. The paper concludes that the empirical literature is lacking in conclusive evidence that privately owned water utilities are more efficient than comparable publicly owned water utilities. Nonetheless, it is worth remembering that many of the empirical studies do not test the predictions of a specific theoretical model for performance differences[10]. As a result, it is difficult to determine which of the theoretical models predicting the superiority of private firms has been rejected.

[10] Three models could be tested: Principal-agent, Property Rights and Public Choice theories. In a principal-agent relationship, the task of the owner is to design a contract that provides the manager with the incentive to choose the strategy that maximises the owner's welfare. The challenge for the owner is that, in a world of asymmetric information and uncertainty, the managers' effort cannot be monitored and contracts cannot be enforced in a costless manner. A significant issue, then, in comparing public and private ownership is their relative efficacy in providing managers with incentives to act consistently with the enterprise's goals.

Property rights theory argues that private-sector owners, ad residual claimants, have more clearly defined incentives to push for efficient decision-making by managers. The same logic applies to the firm's creditors and also to owners of other firms considering a potential takeover. In contrast, politicians, senior bureaucrats and tax-payers have attenuated property rights to the gains associated with improved public-sector agency performance and, as a result, have diminished incentives to push for improvements.

Public choice theory emphasises the potential for inefficient behaviour on the part of public-sector managers since they are assumed to act in their own self-interest.

References

Bhattacharyya, A., E. Parker y K. Raffie (1995). "Technical Inefficiency of Rural Water Utilities," Journal of Agricultural and Resource Economics 20:2, pp. 373-391

Berg, Sanford and Chen Lin (2005). "Consistency in Performance Rankings: The Peru Water Sector." May 6.

Bosworth, D., P. Stoneman and E. Thanassoulis (1996). "The measurement of comparative total efficiency in the sewerage and water industry: An exploratory study," Report commissioned by the Office ox Water Services, October.

Bottasso, A. and M. Conti (2003). "Cost Inefficiency in the England and Welsh Water Industry: An Heteroskedastic Stochastic Cost Frontier Approach", Economics Discussion Papers, University of Essex, Department of Economics.

Bosworth, Derek, Paul Stoneman and Emmanuel Thanassoulis (1996). "The Measurement of Comparative Total Efficiency in the Sewerage and Water Industry: An Exploratory Study". A Report to and Commissioned by the Office of Water Services (OFWAT).

Clarke, George R.G., Katrina Kosec, and Scott Wallsten (2004). "Has Private Participation in Water and Sewerage Improved Coverage? Empirical Evidence from Latin America," Working Paper 0402 (January), AEI-Brookings Joint Center for Regulatory Studies.

Crampes, C, N. Niette and A. Estache (1997). "What Could Regulators Learn from Yardstick Competition? Lessons for Brazil's Water and Sanitation Sector. Mimeo. The World Bank.

Estache, Antonio and Martín Rossi (1999). Estimación de una frontera de costos estocástica para empresas del sector agua en Asia. Serie Textos de Discusión N° 4. CEER/UADE. Buenos Aires, abril.

Estache, Antonio and M. Rossi (2002). "Comparing the Performance of Public and Private Water Companies in Asia and Pacific Region. What a Stochastic Costs Frontier Shows". Policy Research Working Paper. Washington, The World Bank.

Estache, Antonio and Eugene Kouassi (2002). Sector Organization, Governance, and the Inefficiency of African Water Utilities. Policy Research Working Paper 2890. Washington, The World Bank.

Fraquelli, Giovanni and Valentina Moiso (2005). Cost Efficiency and Economies of Scale in the Italian Water Industry. XVII Conferenza Societá Italiana di Economía Pubblica. Pavia, Universitá, 15-16 settembre 2005.

Lin, Chen (2005). "Service Quality and Prospects for Benchmarking: Evidence from the Peru Water Sector", Public Utility Research Center, University of Florida, P. O. Box 117142, Gainesville, FL 326117142. Revised April 25.

Mobbs, Peter and Edward Glennie (2004). "Econometric modelling with ADERASA data & indicator values", WRc (Draft).

Moreira, Ajax R. B. and Thais C. R. Fonseca (2005). "Comparando Medidas de Productividad: DEA, Frontera de Producción Estocástica," Texto para discusión 1069, IPEA, Feb.

Ofwat (2002). Water and Sewerage Services Unit Costs and Relative Efficiency, Birmingham, Office of Water Services.

Price, Jonathan (1993). "Comparing the Cost of Water Delivered. Initial Research into the Impact of Operating Conditions on Company Costs". Costs and Performance Division. OFWAT. Birmingham (March).

Renzetti, Steven and Diane Dupont (2003). “Ownership and Performance of Water Utilities”. Greenleaf Publishing GMI 42, Summer.

Sabbioni, Guillermo (2005). Econometric Measures of the Relative Efficiency of Water and Sewerage Utilities in Brazil. Public Utility Research Center, University of Florida, May 10.

Saal, David and David Parker (2005). Assessing the Performance of Water Operations in the English and Welsh Water Industry: A Panel Input Distance Function Approach. Aston Business School Research Paper RP0502. Aston University. Birmingham, January.

Saal, D. and Scott Reid (2004). “Estimating Opex Productivity Growth in English and Welsh Water and Sewerage Companies: 1993-2003,” Aston Business School Working Paper RP0434.

Saal, David, David Parker and Tom Weyman-Jones (2004). Determining the Contribution of Technical Efficiency and Scale Change to Productivity Growth in the Privatized English and Welsh Water and Sewerage Industry: 1985-2000. Aston Business School Research Paper RP0433. Aston University. Birmingham, December.

Saal, D. y D. Parker, 2001. “Productivity and Price Performance in the Privatized Water and Sewerage Companies of England and Wales,” Journal of Regulatory Economics 20:1, pp. 61-90

Stewart, Mark (1993). “Modelling Water Costs 1992-93. Further Research into the Impact of Operating Conditions on Company Costs”. OFWAT. Birmingham.

Stewart, Mark (1994). “Modelling Sewerage Costs 1992-93. Research Into the Impact of Operating Conditions on the Costs of the Sewerage Network”. OFWAT. Birmingham. (1993)

Tupper, Henrique Cesar, and Marcelo Resende (2004). “Efficiency and Regulatory Issues in the Brazilian Water and Sewage Sector: An Empirical Study,” Utilities Policy 12, pp. 29-40.

Woodbury, Kim and Brian Dollery (2003). Efficiency Measurement in Australian Local Government: The Case of NSW Municipal Water Services. Working Paper Series in Economics. University of New England, School of Economics.

CEER Working Paper Series

To order any of these papers, or all of these, see instructions at the end of the list. A complete list of CEER Working Papers is displayed here and in our web site

WPS 1. *Laffont, Jean Jacques: Translating Principles Into Practice in Regulation Theory (March 1999)*

WPS 2. *Stiglitz, Joseph: Promoting Competition in Telecommunications (March 1999)*

WPS 3. *Chisari, Omar, Antonio Estache, y Carlos Romero: Winners and Losers from Utility Privatization in Argentina: Lessons from a General Equilibrium Model (March 1999)*

WPS 4. *Rodríguez Pardina, Martín y Martín Rossi: Efficiency Measures and Regulation: An Illustration of the Gas Distribution Sector in Argentina (April 1999)*

WPS 5. *Rodriguez Pardina, Martín Rossi and Christian Ruzzier: Consistency Conditions: Efficiency Measures for the Electricity Distribution Sector in South America (June 1999)*

WPS 6. *Gordon Mackerron: Current Developments and Problems of Electricity Regulation in the European Union and the United Kingdom (November 1999)*

WPS 7. *Martín Rossi: Technical Change and Efficiency Measures: The Post-Privatisation in the Gas Distribution Sector in Argentina (March 2000)*

WPS 8. *Omar Chisari, Martín Rodriguez Pardina and Martín Rossi: The Cost of Capital in Regulated Firms: The Argentine Experience (May 2000)*

WPS 9. *Omar Chisari, Pedro Dal-Bó and Carlos Romero: High Tension Electricity Network Expansions in Argentina: Decision Mechanisms and Willingness-to-Pay Revelation (May 2000).*

WPS 10. *Daniel A. Benitez, Antonio Estache, D. Mark Kennet, And Christian A. Ruzzier. Potential Role of Economic Cost Models in the Regulation of Telecommunications in Developing Countries (August 2000).*

WPS 11. *Martín Rodríguez Pardina and Martín Rossi. Technical Change and Catching-up: The Electricity Distribution Sector in South America (November 2000).*

WPS 12. *Martín Rossi and Iván Canay. Measuring Inefficiency in Public Utilities: Does the Distribution Matter? (April 2001).*

WPS 13. *Quesada, Lucía. Network Competition and Network Regulation (July 2001).*

WPS 14. *Rossi, Martín and Christian Ruzzier: Reducing the Asymmetry of Information Through the Comparison of the Relative Efficiency of Several Regional Monopolies (July 2001).*

WPS 15. *WPS 15. Ferro, Gustavo: Political Risk and Regulatory Risk: Issues in Emerging Markets Infrastructure Concessions (August, 2001).*

WPS 16. *Margaretic, Paula, María Fernanda Martínez and Diego Petrecolla: The effectiveness of Antitrust Enforcement in Argentina, Chile and Perú during the 90' (March, 2005).*

WPS 17. *WPS 17. Chisari, Omar, Antonio Estache, Germán Lambardi and Carlos Romero: Trade balance effects of infrastructure services liberalization and of their regulation (March, 2005).*

WPS 18. *Chisari, Omar and Lucía Quesada: Trade balance contraints and optimal regulation (March 2005)*

WPS 19. Ferro, Gustavo: Options for Radical Reforms to Pension Systems: Chilean and Swedish Models Compared (April 2005)

WPS 20. Del Aguila, Virginia: Establishing global competition standards: Achievable Mission or Utopia? (April 2005)

WPS 21. Ferro, Gustavo and Carlos Romero: A cost frontier for Pension Funds in Argentina. (April 2006)

WPS 22. Ferro, Gustavo and Carlos Romero: Efficiency in water and sanitation sector. A survey on empirical literature (May 2007)